# Waveguide-to-microstrip transition at G-band using elevated E-plane probe

# Waveguide-to-microstrip Transition at G-band using Elevated E-plane Probe

O. Donadio, K. Elgaid and R. Appleby

A rectangular waveguide-to-microstrip transition operating at G-band is presented. The E-plane probe, used in the transition, is fabricated on Semi-Insulating Gallium Arsenide (SI-GaAs) and it is elevated on the substrate. This configuration reduces interaction with semiconductor material. The elevated probe is suitable for direct integration with Monolithic Microwave Integrated Circuits (MMICs). Measured results show return loss better than -10db between 150 and 200 GHz and -4dB insertion loss at centre band (180GHz) for two transitions in back-to-back configuration.

*1. Introduction*: MMICs' technology extends its uses at Millimeter-Waves (MMW), as G-band (140-220 GHz) [1] improving systems image resolution for applications as medical imaging, aircraft landing aids and detection of concealed weapons. However, these systems tend to use rectangular waveguides as low loss interconnection elements. Hence, the transition between Radio Frequency (RF) circuitry and rectangular waveguide represents a crucial part of the system's design.

Different configurations have been investigated in the past [2]-[4] and few of them involved material with high dielectric constant [4]. Moreover, at high frequencies as G-band there is a tendency to fabricate the RF circuitry and the transition respectively on two different substrate materials keeping a hybrid structure and involving supplementary wirebonds connections [1]. The RF circuits at MMW are often fabricated on high dielectric constant substrates and their integration with the transition has advantages as low production cost and reduced size. Recent publications [5]-[6] have exploited this integration at MMW and sub-MMW, highlighting the delicate manufacture and assembly.

In this paper, a rectangular waveguide-to-microstrip transition at G-band using an Elevated E-plane Probe is proposed for the first time. The probe is fabricated directly on SI-GaAs and it is connected to a 50Ω microstrip line without any extra matching network.

*2. Elevated E-plane Probe Design*: The transition is designed using SI-GaAs as substrate material. The probe, elevated from the semiconductor material and supported by gold metal posts, protrudes into the waveguide [2] through an aperture on one of its broad sides as shown in Fig. 1a. The substrate is parallel to the E-field and is aligned along with the direction of propagation of the waveguide.

The performance of the transition is controlled by tuning three fundamental parameters: length of the probe L, width of the probe W and the backshort D, distance between the probe and the waveguide termination as illustrated in Fig. 1b.

The elevation of the probe from the substrate is a new extra tuning parameter introduced in the design. By uplifting the probe, the interaction with the substrate material is mitigated reducing the return loss ($S_{11}$) of the transition as shown in the parametric analysis for different heights of the probe in Fig. 2.

Dimensions of the aperture on the waveguide side, where the substrate is mounted, are chosen to be 500µm × 175µm for GaAs material 50µm thick, preventing unwanted modes to propagate.

The simulation and parametric optimization are carried out using the Ansys High Frequency Structure Simulator, HFSS 11, based on the Finite Elements Method (FEM) technique. Optimized dimensions for the parameters are found to be W = 100µm, L = 280µm and D = 500µm. With an elevation height of H = 6µm the probe structure can be fabricated with only three gold supports located along the centreline. One of the supports also works as a pin contact between the probe and the 50Ω microstrip line.

*3. Fabrication and Assembly*: The fabrication consists of two major processes: one based on III-V MMIC air-bridge technology for the elevated probes and one for the rectangular waveguide housing.

*3.1. Probe Fabrication*: A SI-GaAs wafer with a dielectric constant $\varepsilon_r$ =12.9 and thickness of 630µm is used. A 50Ω microstrip line with length of 3mm is defined by e-beam exposure and development of a thick layer of PMMA followed by a deposition of 1.2µm of gold by electron beam evaporation and lift-off procedure. Subsequently, photolithographic techniques are employed to define posts and probe profiles and then a process of gold electroplating was used to grow the elevated structures. At this stage, the wafer is bonded upside down on a sapphire carrier for a further back-side thinning process that brings the thickness of the SI-GaAs wafer from 630µm to 50µm. The last step entails an extra photolithographic process and gold evaporation to define the ground planes for the microstrip lines. The substrate material is then carefully de-bonded from the sapphire and it is scribed and cleaved for device separation. Fig. 3 shows an SEM image of the fabricated probe.

*3.2. Waveguide Housing Fabrication*: The waveguide housing was designed to characterise two waveguide-to-microstrip transitions in back-to-back configuration.
The housing was fabricated in split blocks of brass by using a CAT-3D Computer-Numerically-Controlled (CNC) milling machine. Standard MIL-F-3922-67B flanges [7] were also defined on the input and output sides of the split blocks for the connection with the measurement instrument. Finally the two transitions were aligned and bonded into the housing using silver conductive epoxy as shown in Fig. 4. An optical micrograph of the resulting probe protruding into the rectangular waveguide is also shown in Fig. 5.

*4. Experimental Results*: Measurements were performed using an Agilent Performance Network Analyser (PNA) and 140-220GHz OML heads. A Thru-Reflection-Load (TRL) calibration technique and WR-05 calibration standard were used to calibrate the Vector Network Analyser (VNA).

Simulated and measured S-parameters results for two transitions separated by 3mm of microstrip line are presented and compared in Fig. 6 showing good agreement. The difference in the level of the return loss (S11) in the upper part of the G-band is due to the relatively large fabrication tolerance (± 20µm) of the CNC milling machine used to define the waveguide flanges profile. The measured response shows reflection loss better than -10dB from 150GHz to 200GHz and insertion loss of -4dB at the centre of the G-band for two transitions in back-to-back configuration.

*5. Conclusion:* The use of an elevated probe has been demonstrated for the first time extending the concept of E-plane probe for waveguide-to-microstrip transition. The elevation of the probe, as new tuning parameter, mitigates the interaction with substrate and reduces the return loss (S11) of the transition. Since the elevated E-plane probe is fabricated on SI-GaAs, it allows its integration directly with other MMICs resulting in reduced size and reduced costs in fabrication and assembly.

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**Figure captions:**

Fig. 1 Configuration of the proposed Elevated E-probe protruding into the rectangular waveguide (a) and its top view (b)

Fig. 2 Return loss of the waveguide-to-microstrip transition for different elevations of the probe

Fig. 3 SEM image of the elevated probe and supporting posts

Fig. 4 Fabricated split blocks waveguide, housing the waveguide-to-microstrip transitions with elevated probe

Fig. 5 Elevated E-plane probe aligned and bonded into the waveguide housing

Fig. 6 Simulated and measured S-parameters results for two waveguide transitions in back-to-back configuration and separated by 3mm of microstrip line.

Figure 1

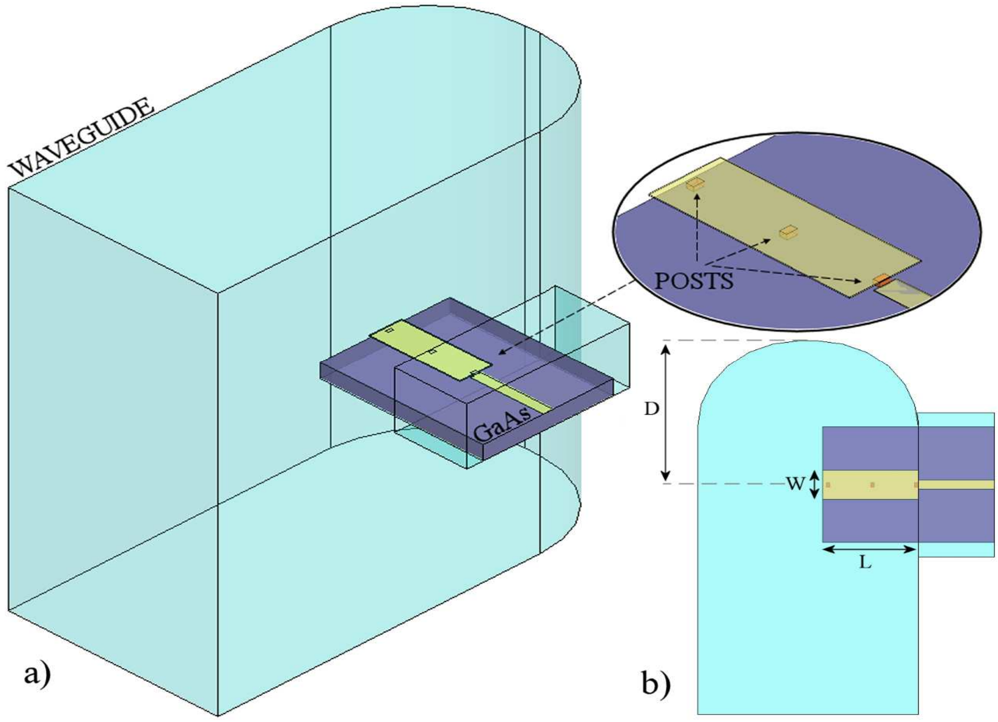
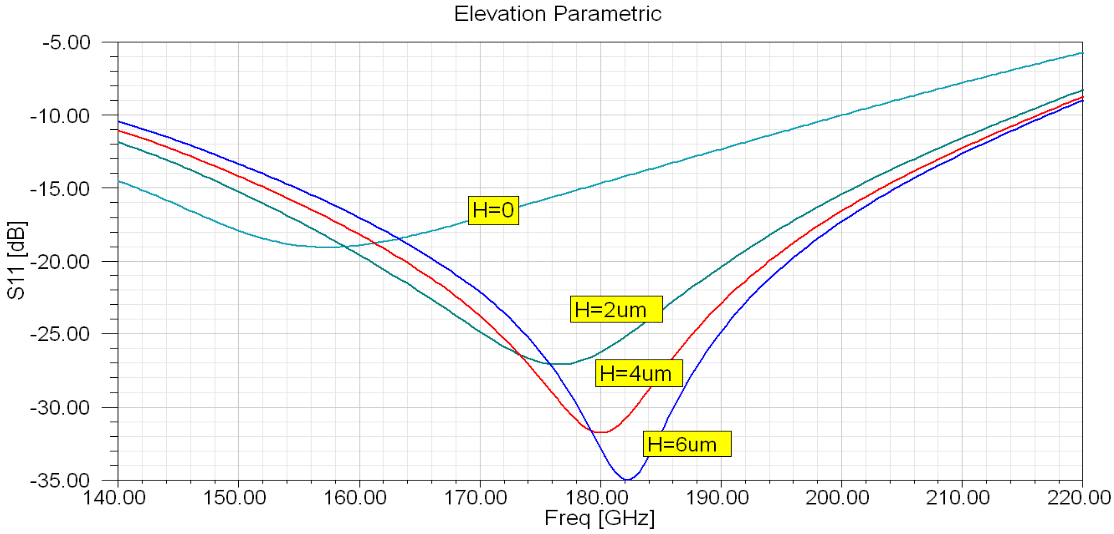


Figure 2



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H=0
H=2um
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Figure 3

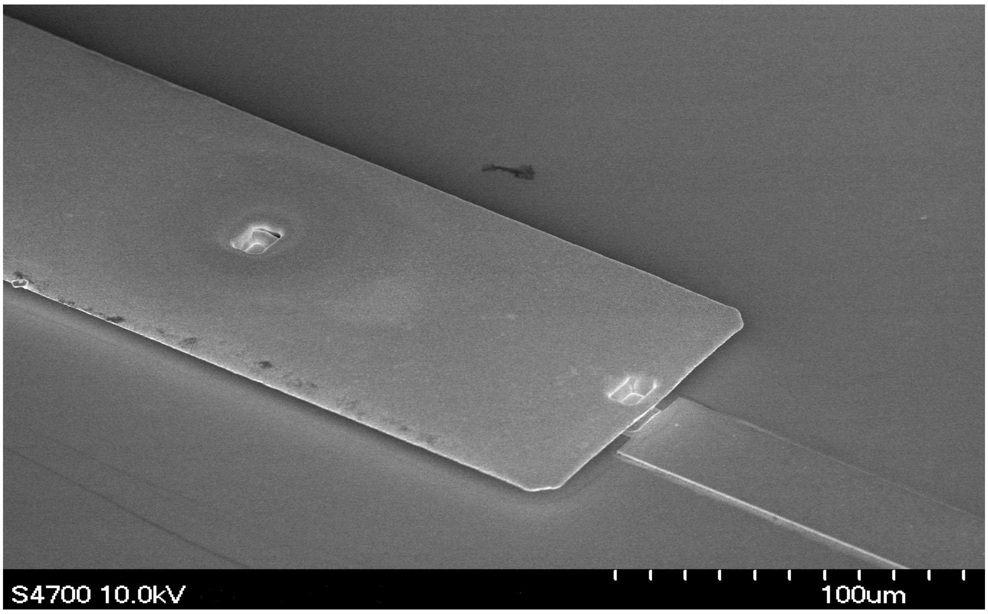


Figure 4

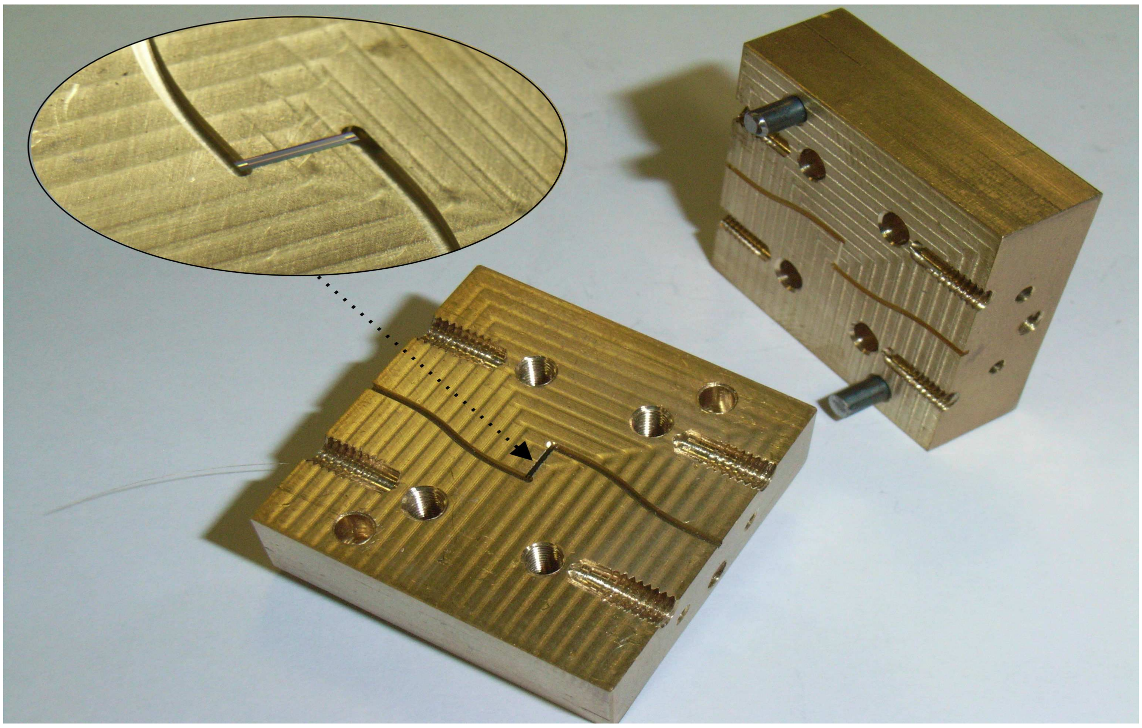


Figure 5

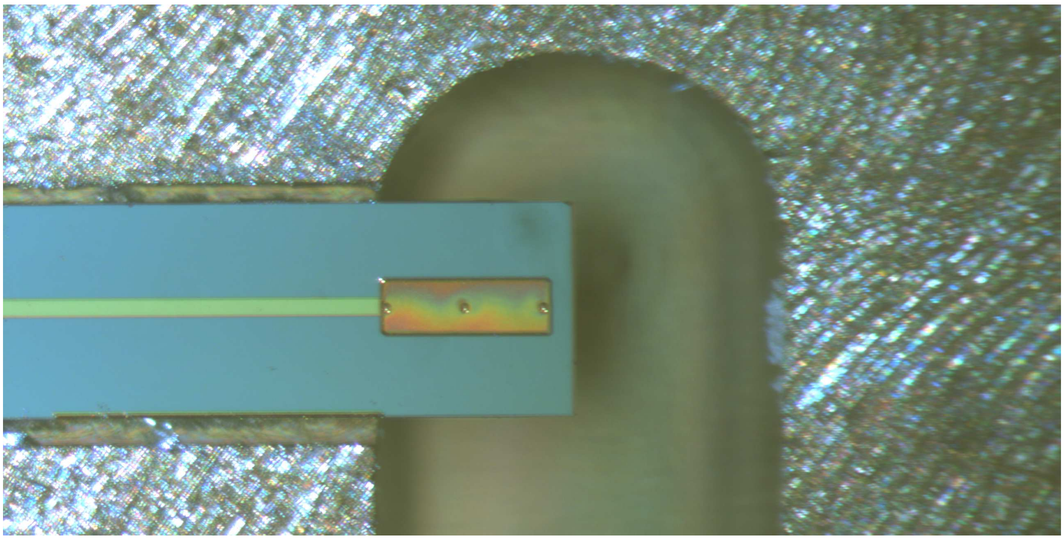
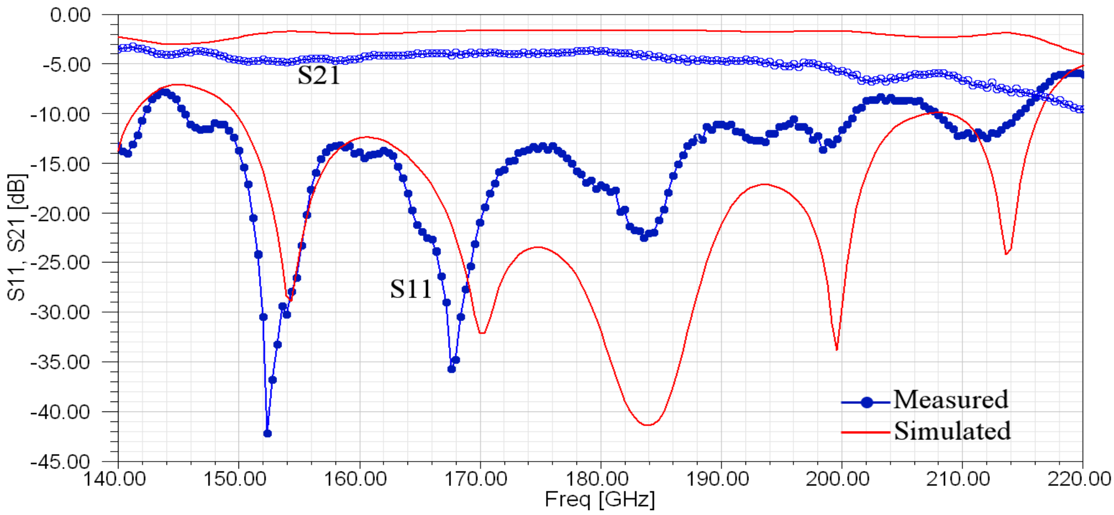


Figure 6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